[redacted]

7 August 1964
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MEMORANDUM

STATINTL

STATINTL To: [redacted]

From:

STATINTL

Subject: Diffuse Density and the [redacted] Densitometer STATINTL

CC: [redacted]

INTRODUCTION

STATINTL The purpose of this memorandum is to bring to light some dis- STATINTL crepancies and their causes between diffuse density as determined by the [redacted] densitometer and diffuse density as defined by [redacted] PH 2-19-1959. The discrepancies became apparent when an attempt was made STATINTL to calibrate the [redacted] densitometer with a set of [redacted] glass filters rather STATINTL than the calibration step wedge supplied by [redacted] The density differences STATINTL that were observed were often greater than 0.2 with the glass filters always reading lower.

NUMERICAL APERTURES

It was immediately discovered that the numerical aperture of the source was set at 0.4 which corresponds to a full cone angle of 47°. This is far greater than the 20° maximum cone angle specified by the National Bureau of Standards.* The source box was opened, and the source geometry adjusted to provide a numerical aperture of 0.05 which is well within the maximum allowed angle.

STATINTL * Private Communication - [redacted] National Bureau of Standards

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DENSITY DIFFERENCE

STATINTL The [redacted] densitometer was calibrated from the [redacted] calibration wedge and density readings were taken of every step in the wedge as STATINTL well as each [redacted] glass filter of the series. The results are presented in STATINTL Table 1. Density differences of 0.01 or 0.02 between the values quoted by [redacted] and those read on their instruments are normal and are a result of limitations due to meter scale resolution, precision with which the calibrating potentiometers can be adjusted, and possibly the stability of the light source. STATINTL The discrepancies between the stated values of the [redacted] glass filter densities and their values as measured by the [redacted] densitometer are large. At high STATINTL densities the discrepancy is 0.3 density units.

COLOR DIFFERENCES

Since the numerical aperture of the source had been adjusted to a small value, and the light emerging from the sample film was "collected" entirely by a diffuser in contact with the sample, the geometry of the optics was not suspected of being in error. Attention was then turned to the possibility that the source "color" (intensity distribution with wavelength) was different than those for which the densities had been calibrated.

What is now necessary to know is how diffuse density varies with STATINTL wavelength for both the [redacted] wedge (film) and the [redacted] glass filter STATINTL the overall wavelength response of the [redacted] densitometer. This information STATINTL STATINTL was obtained in a crude but rapid manner by inserting the sample (film or glass) in the calibration filter holder of the [redacted] microdensitometer and scanning a STATINTL [redacted] 33-80-02 wedge interference filter. The overall wavelength STATINTL response of the microdensitometer is approximately the same as the [redacted] densitometer since they both utilize tungsten filament sources and 931A photomultiplier tube detectors. The scanning optics consisted of a narrow slit and a high magnification of the analytical microscope assembly to provide a narrow scanning aperture and hence a narrow wavelength response for the wedge interference filter. In addition, the numerical aperture of the source was kept small to further provide a narrow wavelength response by not allowing oblique rays through the interference wedge.

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[redacted] Calibration Wedge

	Stated	Indicated
1	0.05	0.07
2	0.17	0.18
3	0.31	0.32
4	0.45	0.47
5	0.59	0.62
6	0.74	0.76
7	0.88	0.90
8	1.04	1.06
9	1.21	1.22
10	1.36	1.38
11	1.51	1.52
12	1.64	1.64
13	1.80	1.79
14	1.96	1.95
15	2.11	2.10
16	2.28	2.25
17	2.46	2.43
18	2.62	2.62
19	2.77	2.83
20	2.93	3.03
21	3.09	3.20

[redacted] Filters

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Stated	Indicated
0.21	0.16
0.69	0.57
1.06	0.84
1.51	1.23
1.83	1.50
2.22	1.85
2.60	2.16
3.15	2.75
3.88	3.54

TABLE 1

STATED AND INDICATED DENSITIES

Three scans were taken. The first was with a glass filter of STATINTL density of about 1.5. The second was with the [redacted] calibrating wedge at a density of approximately 1.4. The last scan was carried out with no sample to provide the system response. For each of the two filters the system density values were subtracted from the sample densities for corresponding positions along the interference wedge, and these differences converted to transmission and normalized to a maximum value of unity. The density values for the "system only" were directly converted to transmission and similarly normalized. Finally, a rough wavelength calibration was performed by determining the positions along the interference wedge of four spectral lines of mercury. Figure 1 is a plot of the relative transmission with the wavelengths included. Since the spectral region where large differences are in evidence occur in the region of low system response, the differences in the spectral transmissions of the filters could not mean the difference of a factor of two in overall transmission. Further consideration of spectral differences were not continued.

DETECTOR GEOMETRY

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It was now realized that a poor diffuser could yield erroneous answers even when all the light emerging from the sample was collected.. Consider the geometry in Figure 2 which is symbolic of the detector optics of the [redacted] densitometer. The measurement of the light intensity emerging from the sample takes place in two steps. First, the diffuser samples the light from the sample and becomes a source itself for the detector. Second, the detector samples the light emerging from all points of the diffuser. There are three general classes of defects which when possessed by the diffuser could

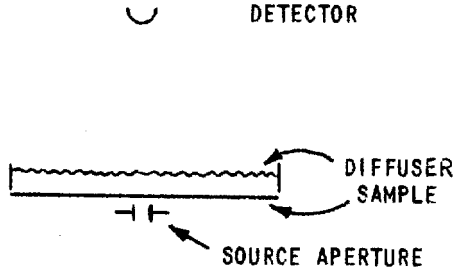
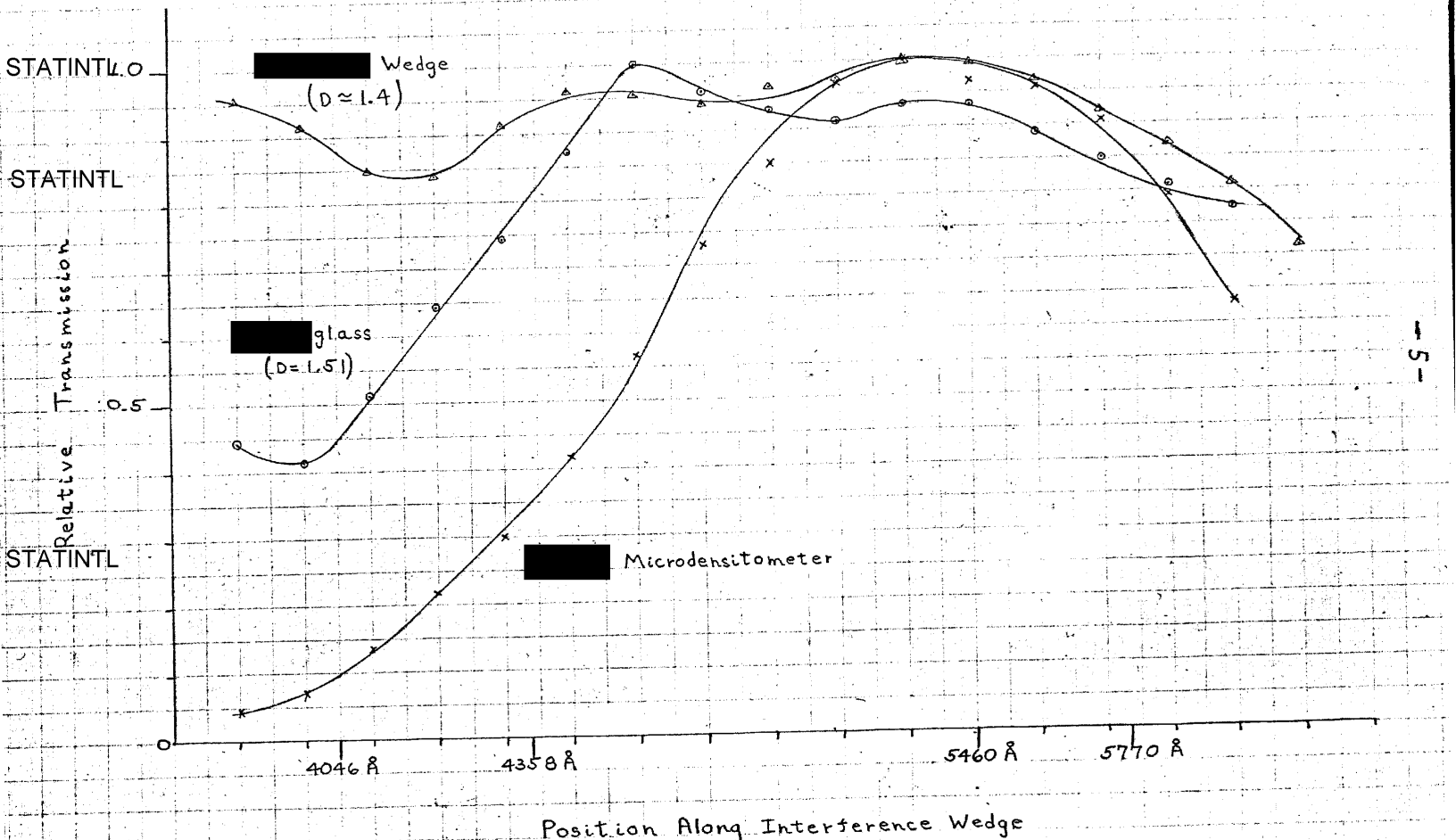


FIGURE 2

DETECTOR GEOMETRY

Fig. (1) – Spectral Response of Filters and System



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yield wrong answers with this geometry. These possibilities are shown in Figure 3. It is necessary that the detector of Figure 2 sample the light leaving

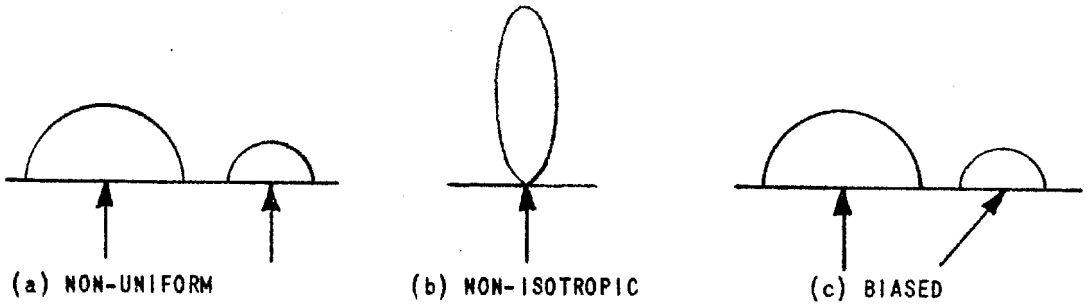

FIGURE 3

DIFFUSER DEFECTS

the diffuser such that it yields a measure of the light entering the diffuser regardless of position or angle of incidence. In Figure 3 the arrows are rays incident on the diffuser, and the curves represent the strength of the emission pattern for the diffuser. Figure 3a simply demonstrates the possibility that the diffuser is not uniform and attenuation through the diffuser depends on which area of the diffuser is used. Figure 3b shows a non-isotropic emission pattern which in the geometry of Figure 2 would give a higher intensity reading in the center of the diffuser than at the border. Figure 3c shows a possible reduction in emission for oblique rays. This would also yield a higher intensity reading in the diffuser center than at the border simply because the rays entering the center are normal and those entering the diffuser near the border are oblique. Therefore, either or both of the defects of Figure 3b or 3c could give a lower density reading for a non-scattering filter (glass) than a scattering filter (film).

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STATINTL Verification that the diffuser was poor was a result of repeating some of the density measurements with additional diffusers between the sample and the [redacted] densitometer diffuser. This reduced the density difference of 0.3, for STATINTL a density of about 1.5, to less than 0.1. It was therefore concluded the [redacted] diffuser is the major source of discrepancies in density readings between the [redacted] glass standards.

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